

Identifying Solar Wind Charge Exchange in XMM-Newton Observations

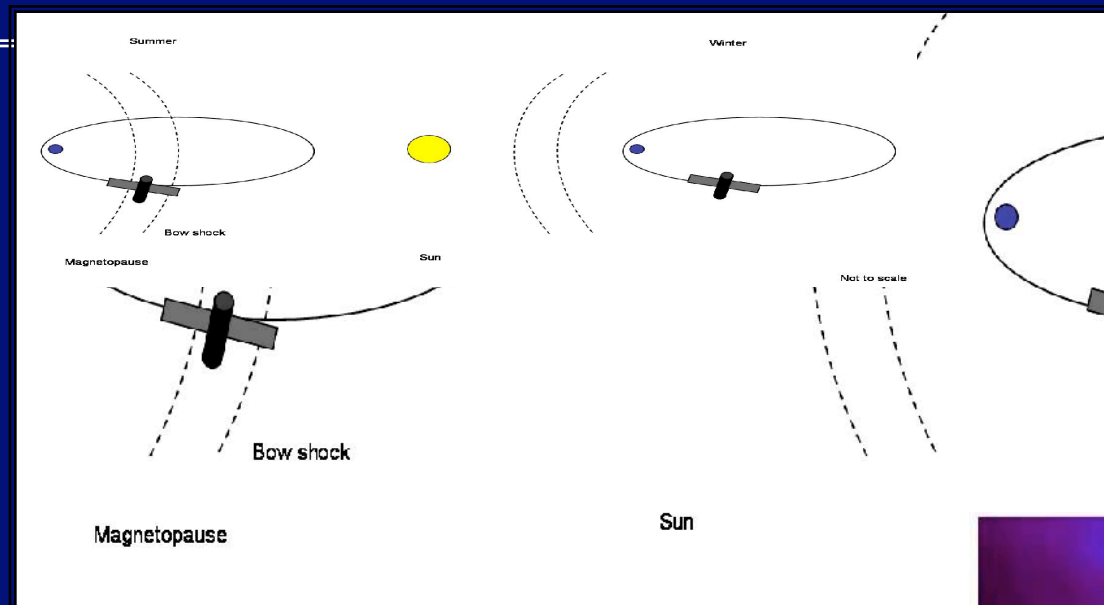
Jenny Carter & Steve Sembay
University of Leicester



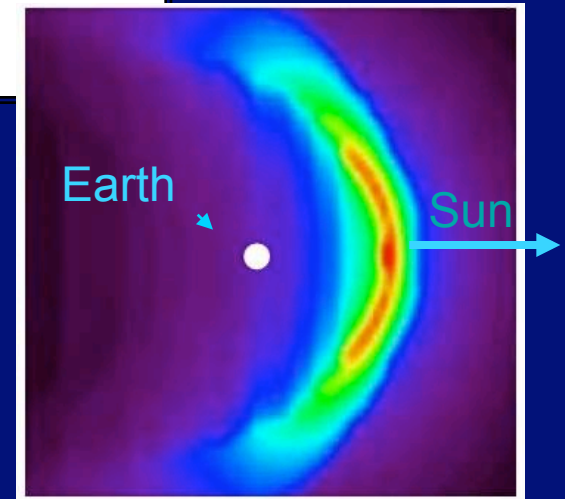
Aims of project

- Identify XMM-Newton observations that have experienced SWCX enhancement during their exposure
 - Identify key indicators of this effect
 - Prepare test parameters
 - Apply to a set of archived observations
 - Analyse results with respect to test parameters
- Look at application of test to whole archive and maybe create a tool for a user?

XMM-Newton and the Earth's magnetosheath



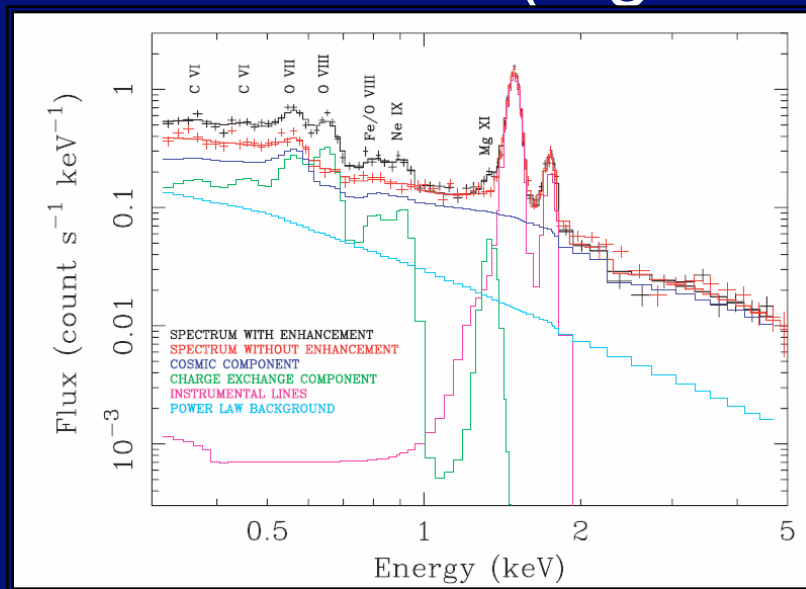
- 48 hour orbit
- Pointing angle will sometimes pass through areas of high X-ray flux
- Depends on pointing and time of year



Robertson & Cravens 2003

Expected SWCX geocoronal X-ray flux characteristics

- Emission lines (e.g. Snowden et al., 2004)



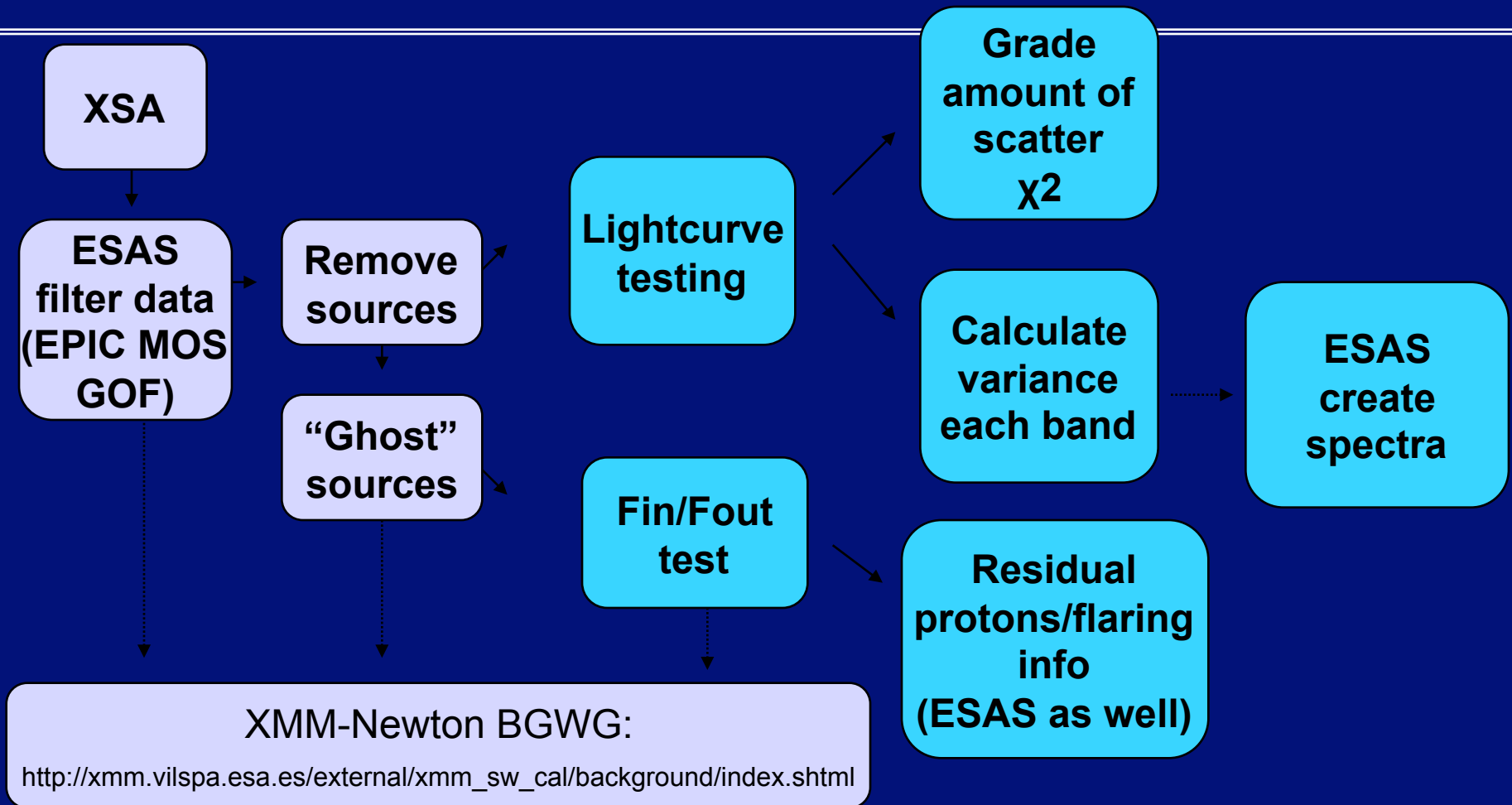
CVI	0.37 keV
CVI	0.46 keV
OVII	0.56 keV
OVIII	0.65 keV
OVIII	0.81 keV
NeIX	0.91 keV
MgXI	1.34 keV

- Short term variability
- Local source, expect pointing dependence

Observations

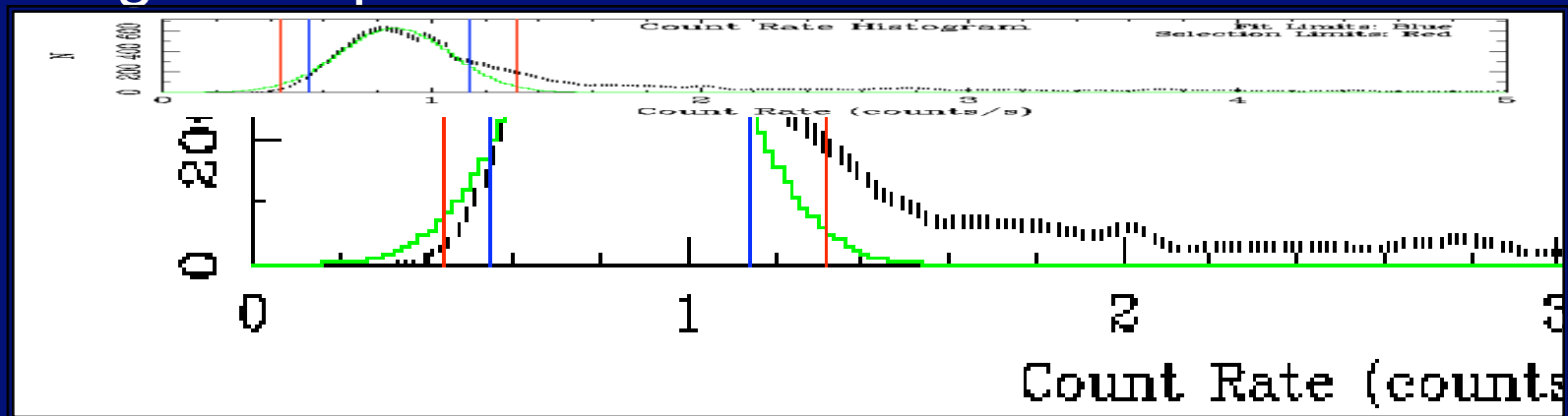
- XMM-Newton XSA archive
- Control subjects
 - Kuntz & Snowden, 2008, A&A, 478, v2
 - HDFN
 - Polaris Flare
 - Groth-Westfall strip
 - Snowden et al., 2004, HDFN
- Around 200 observations (total currently ~1500 revs, ~4300 observations (MOS full-frame))
- Look at ACE data for each observation

Data preparation and tests

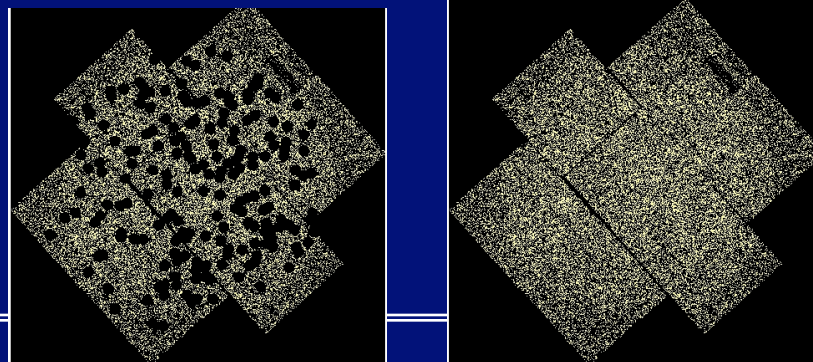


ESAS and source removal

- ESAS software: analysis of diffuse emission, filtering, diagnostic plots



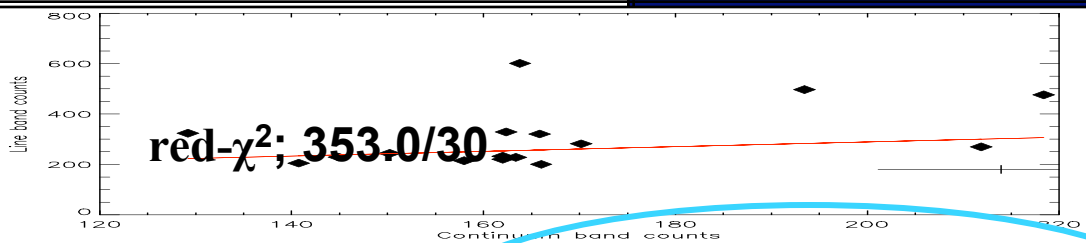
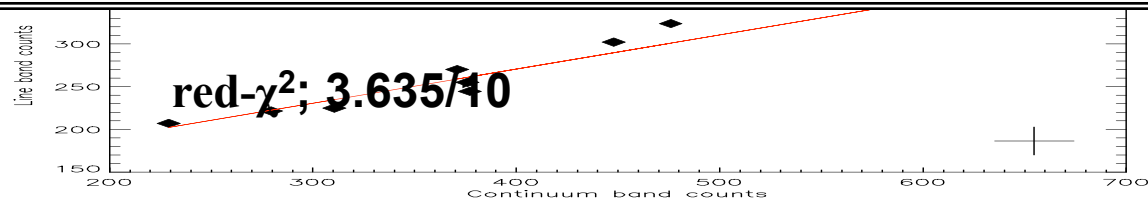
- Point source removal (2XMM catalogue) and ghosting



Important for extra tests later on

Test

- Test for variability in SWCX band
i.e. OVIII (500 – 700 eV)
- Compare to variability of continuum band
(1100 – 1275 eV, 1600 – 1650 eV and 1900 – 2400 eV)
- Test for a lack of correlation between the count rates
- Test ok even for obs. with residual soft proton flaring
- Other tests:
check variance in each individual band
compute in/out-FOV ratio (F_{in_fout})



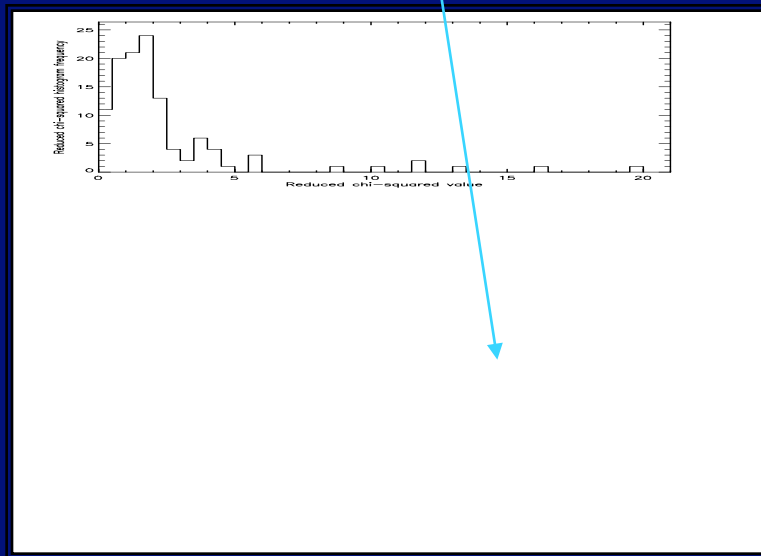
Top table – Carter & Sembay, A&A, 2008, subm.

Case	Observation	Date	Exp. (ks)	dof	reduced- χ^2_{linfit}	χ^2_R	FF ratio	Err. FF ratio	Comment
1	0093552701	2001-01-28	24.17	16	19.62	9.31	1.385	0.08	Weak case SWCX
2	0149630301	2003-09-16	19.77	16	16.03	12.65	1.035	0.07	Strong SWCX
3	0305920601	2005-06-23	15.24	14	13.14	19.79	1.025	0.07	Strong SWCX
4	0070340501	2001-06-18	19.10	8	11.85	15.91	1.628	0.13	Weak case SWCX
5	0150680101	2003-07-26	42.67	30	11.76	4.99	1.147	0.06	Strong SWCX
6	0101040301	2000-11-28	37.21	35	10.16	5.27	1.432	0.07	Weak case SWCX
7	0111550401	2001-06-01	93.37	83	8.88	6.74	1.100	0.04	Snowden et al. (2004)
8	0202370301	2005-01-08	25.85	14	5.74	1.50	1.174	0.05	Low χ^2_R
9	0159760301	2005-11-01	37.88	34	5.66	5.35	1.141	0.04	Bad flaring
10	0127921101	2000-07-23	7.43	6	5.59	5.14	1.180	0.12	Kuntz & Snowden (2007)
11	0127921001	2000-07-21	54.04	53	4.70	3.03	1.389	0.06	Kuntz & Snowden (2007)
12	0150480501	2002-12-22	21.93	11	4.45	1.29	1.356	0.10	Low χ^2_R
13	0136000101	2002-04-17	17.75	17	4.14	3.71	1.397	0.08	Strong case SWCX
14	0146390201	2003-03-29	25.64	18	4.09	3.84	1.100	0.07	Bad flaring
15	0125920201	2000-06-05	23.45	22	4.01	1.00	1.305	0.01	Low χ^2_R
16	0164560701	2004-07-23	31.62	20	3.93	3.50	1.297	0.06	Weak case SWCX
17	0302310501	2005-10-23	23.16	23	3.82	0.64	2.114	0.10	Low χ^2_R
18	0089370501	2002-10-01	49.23	22	3.72	3.24	1.045	0.05	No SWCX
19	0101440101	2000-09-05	49.22	31	3.68	2.81	1.332	0.06	Weak case SWCX
20	0085150301	2001-10-21	31.96	24	3.65	2.21	1.671	0.09	Strong case SWCX
21	0202610801	2004-11-09	17.90	15	3.63	2.19	1.261	0.07	No SWCX
22	0106460101	2000-11-06	54.90	43	3.20	1.54	1.176	0.05	Weak case SWCX
23	0305560101	2005-10-21	23.01	22	3.16	1.62	1.093	0.05	No SWCX
24	0001930301	2001-12-28	24.58	18	3.00	2.08	1.925	0.10	No SWCX
25	0110661601	2002-03-19	7.61	6	2.79	1.47	1.603	0.14	Kuntz & Snowden (2007)

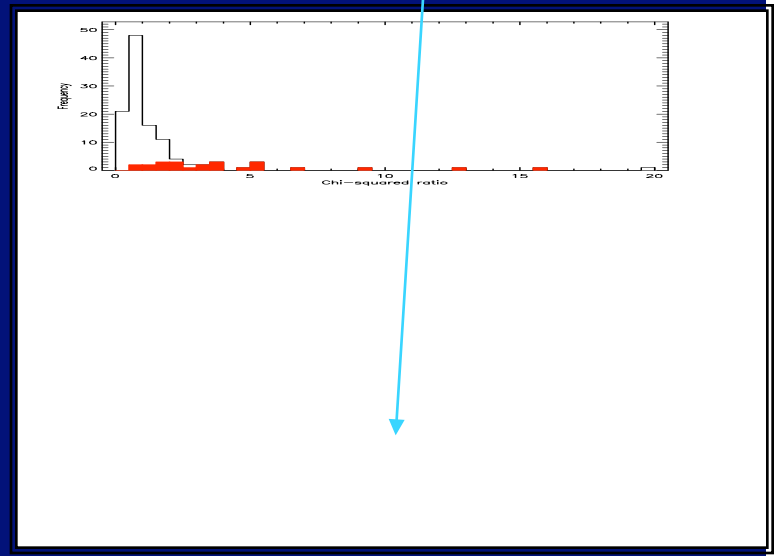
Results

- Control observations with SWCX found in/out top set
- ~11 observations with unpublished SWCX characteristics

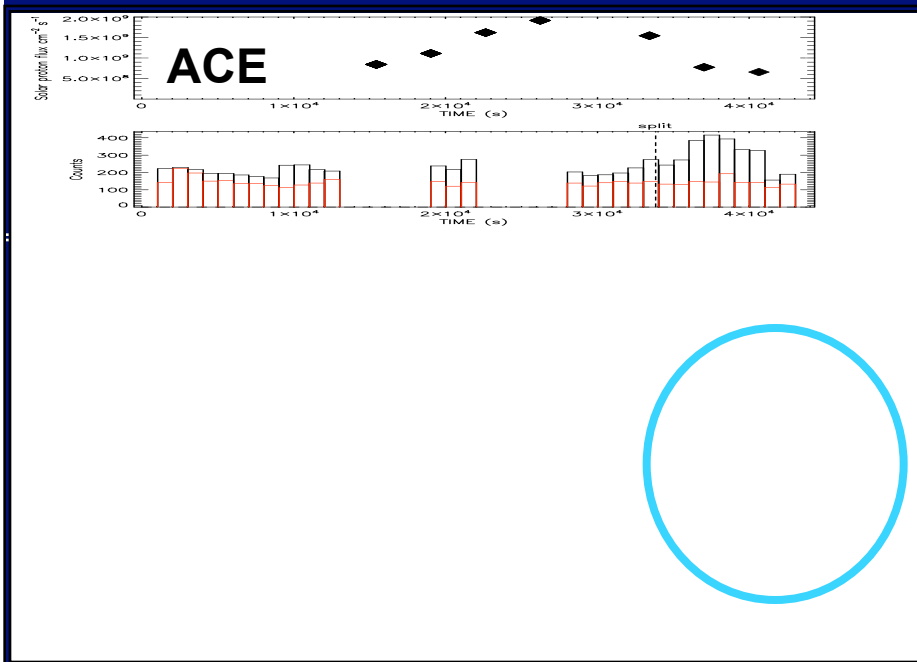
Large χ^2 - SWCX obs.



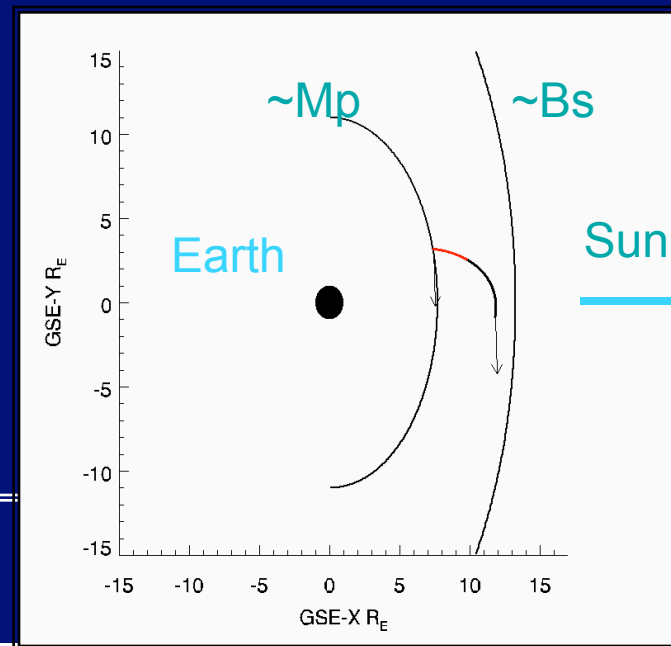
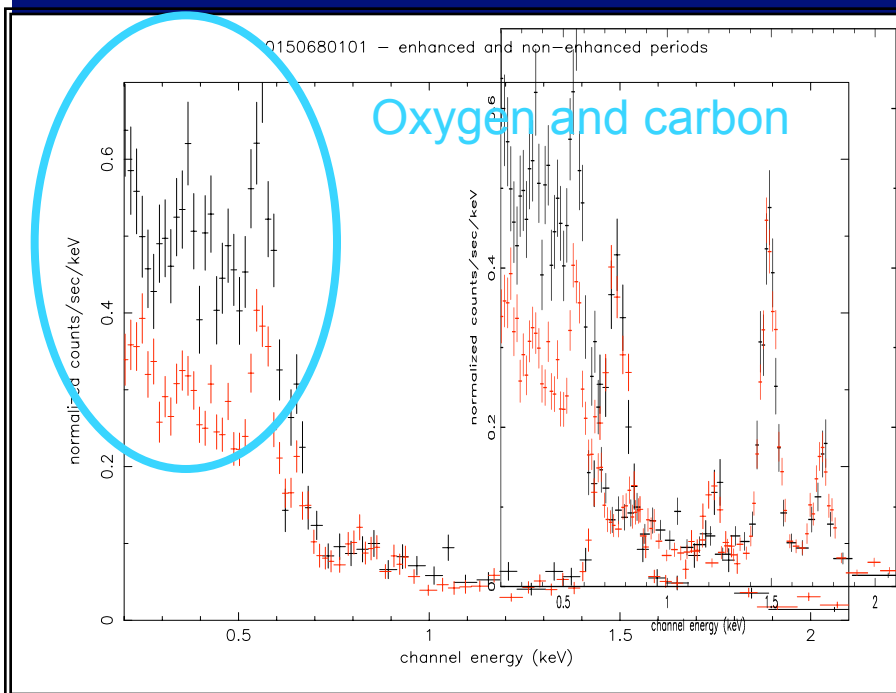
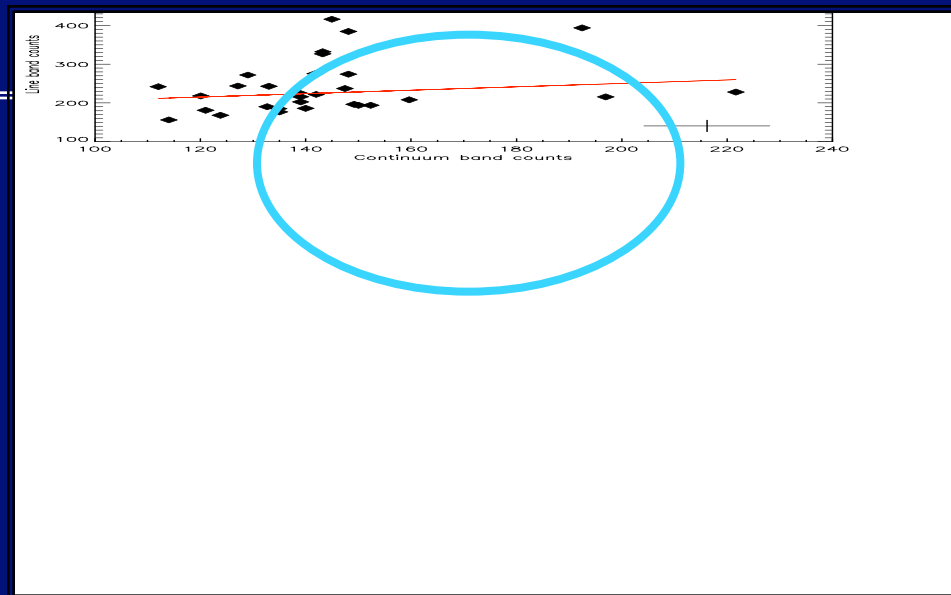
Ratio of variance in each band



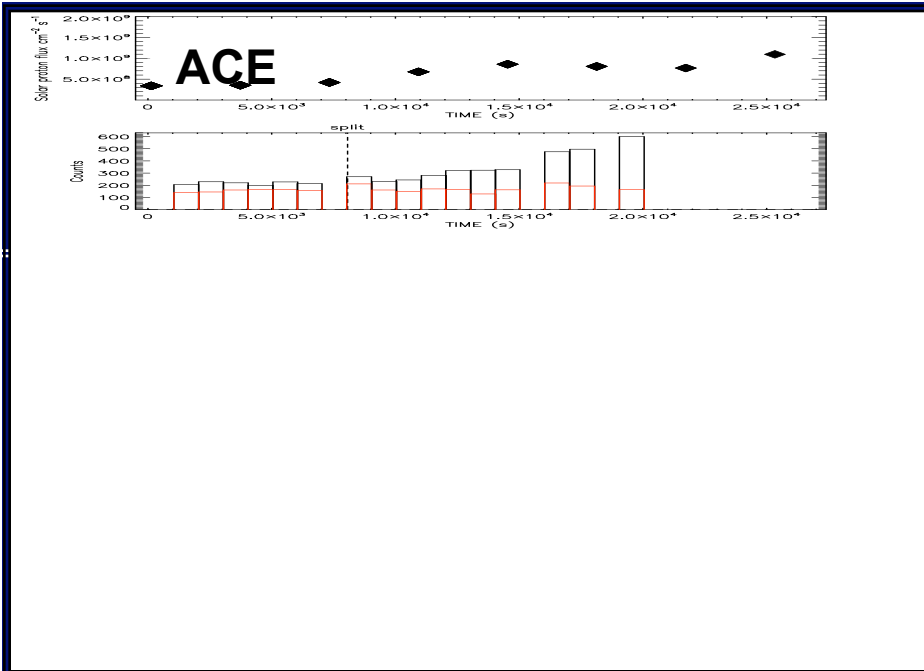
General trends:



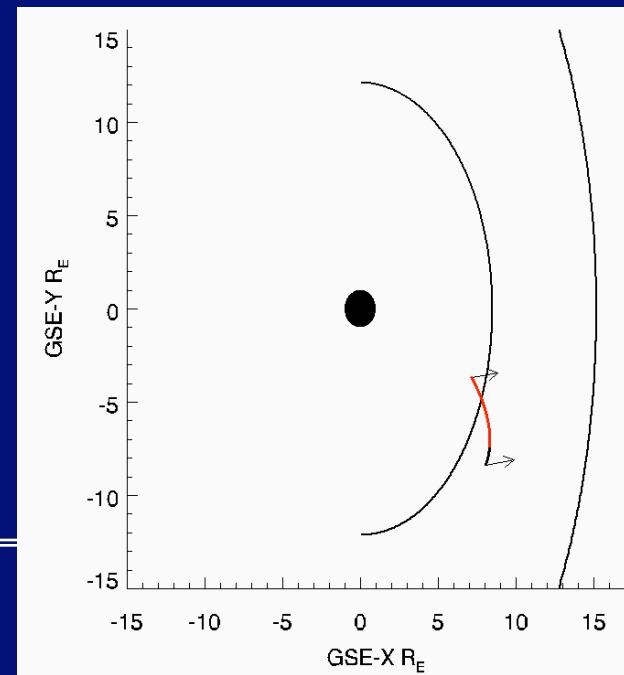
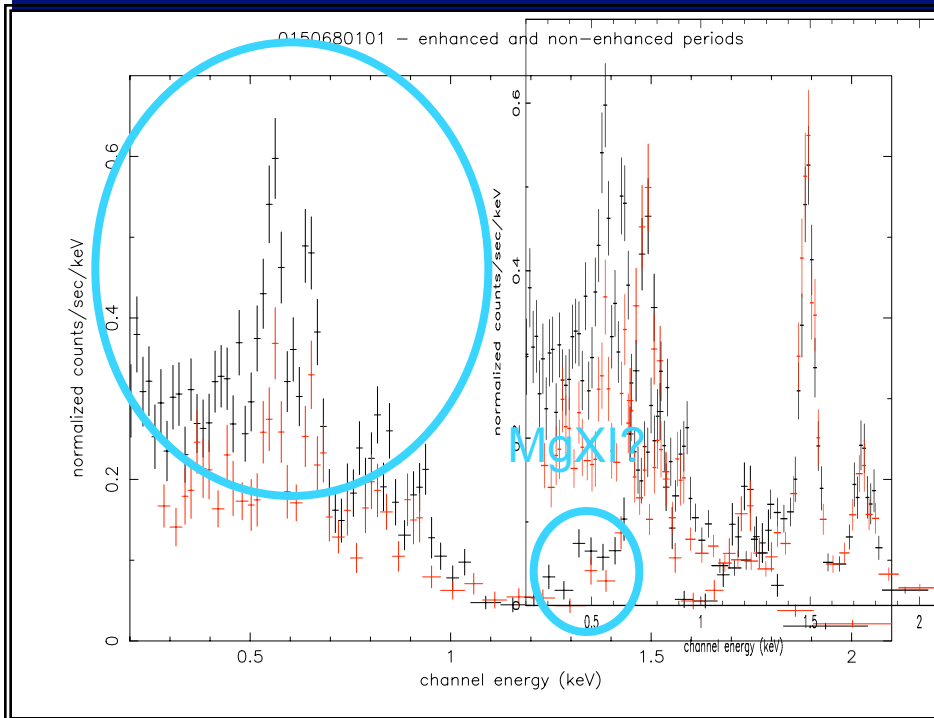
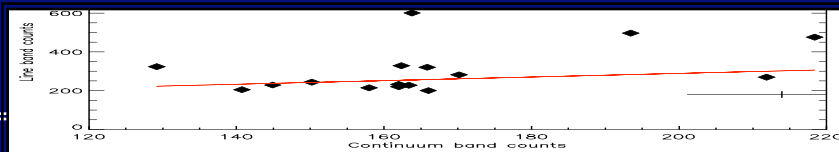
Example: obsn 0150680101



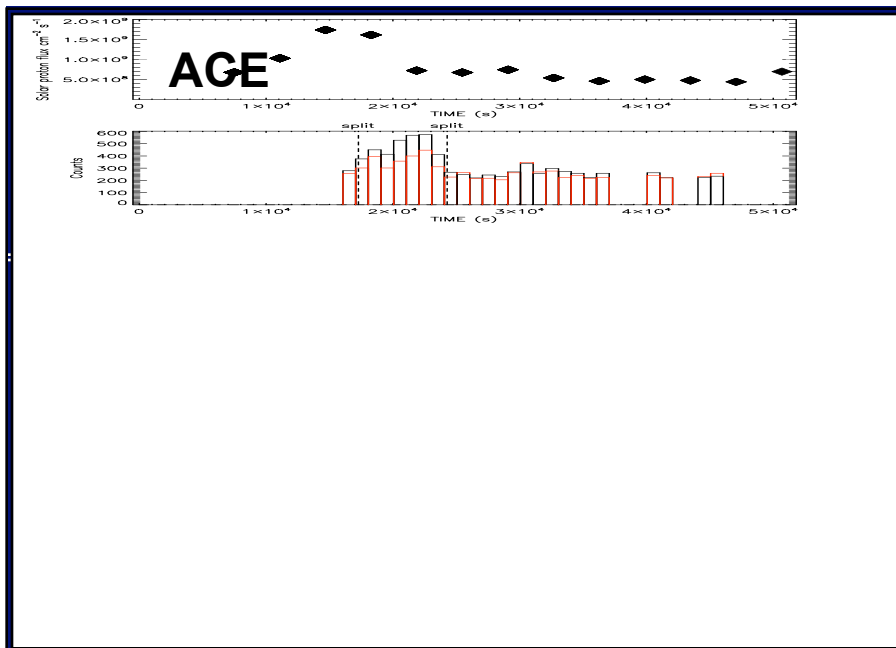
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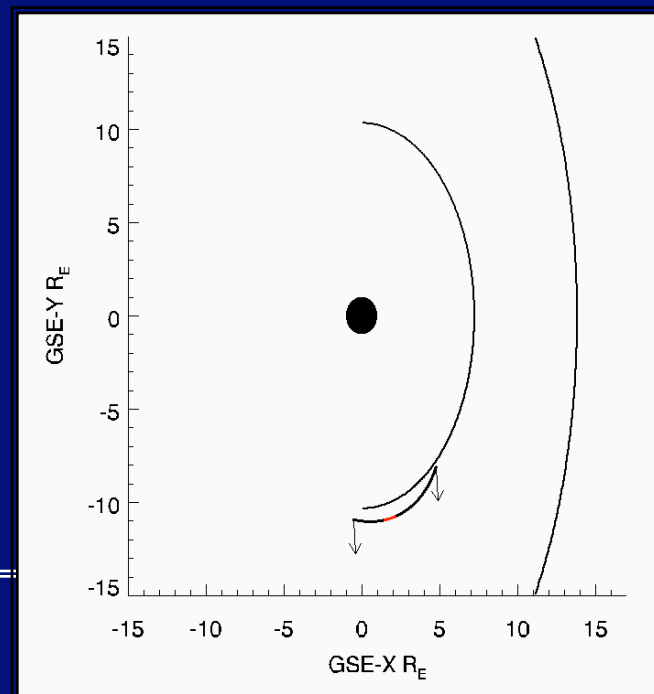
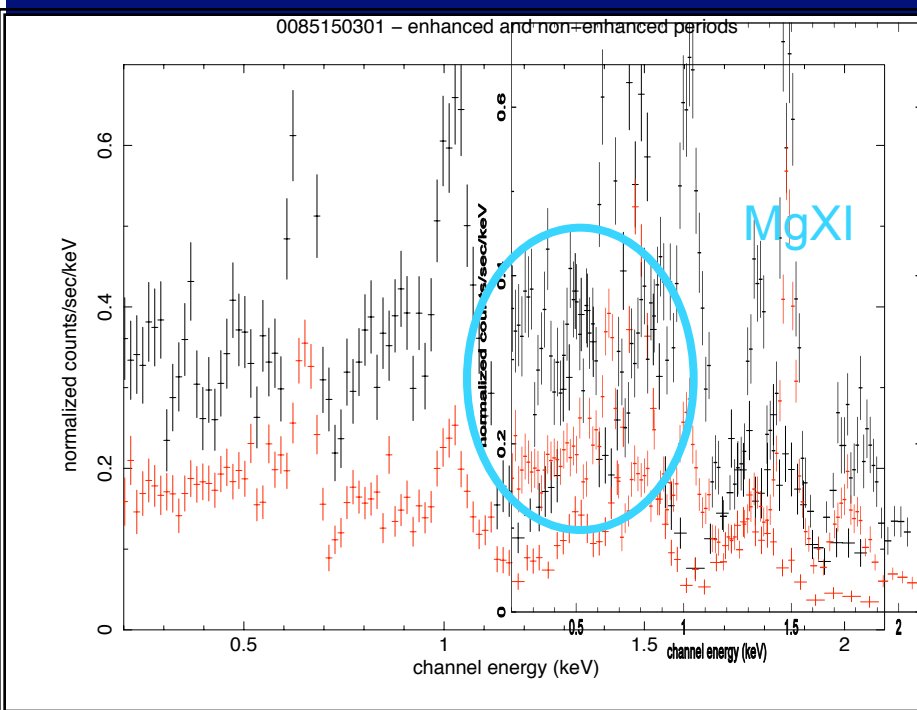
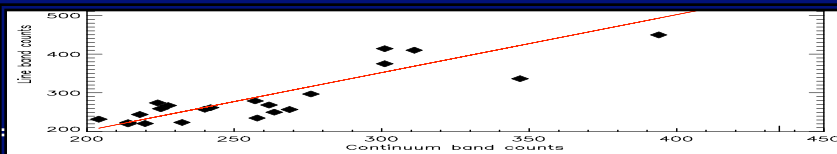
Example: obsn 0149630301



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Example: obsn 0080515301



Local Bubble and Beyond II

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Conclusions

- Successful identification of control subjects
- Identification of new cases of geocoronal SWCX emission (~ 11)
- Some correlation with ACE
- Some correlation with XMM-Newton pointing angle
- Extreme case with many emission lines
- Plans to extend diagnostic and grading technique to entire archive at Leicester





Extra slides



Plan

- Geocoronal neutrals, SWCX and XMM-Newton
- Search for correlation, choice of test
- Observations used
- Results – light curves
- Results – spectra, redistributions of lines
- Results – XMM-Newton position
- Conclusion and future



ESAS filtering, basis

- Main motivation for using ESAS: good for study of diffuse emission
- Filtering based on GTIs to remove obvious soft proton contamination
- Gives judge of residual soft proton contamination
- Background spectra created from filter wheel closed data for particle-induced background

Previous method

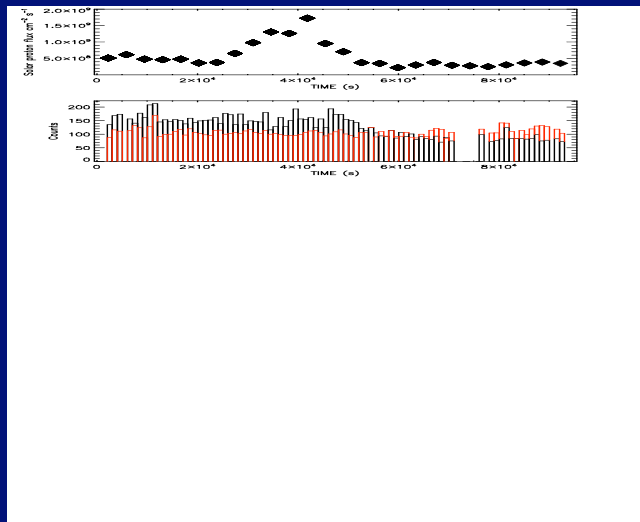
- Normalise lightcurves
- Calculate difference between lightcurves
- Calculate chi-squared distribution function
 - probability that a random variable will have a value greater than or equal to that for the given degrees of freedom providing that the distribution
- Grade with, $\text{grade} = 1 - p$
 - Higher grade, more difference between lightcurves
- Problem: Too sensitive to differences. Formally too much variation between lightcurves when really the difference should not be significant. Residual soft protons needed to be accounted for – variability in the continuum band

XMM-Newton pointing restrictions

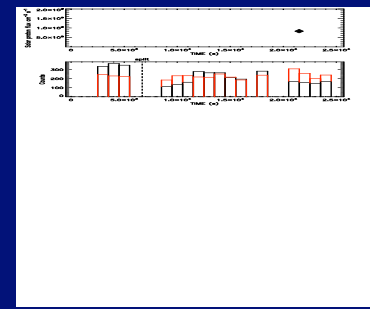
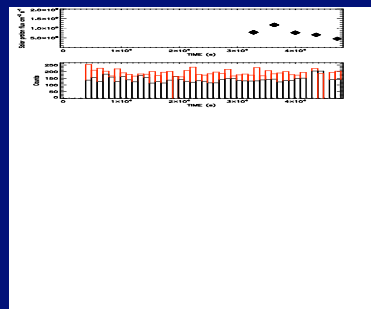
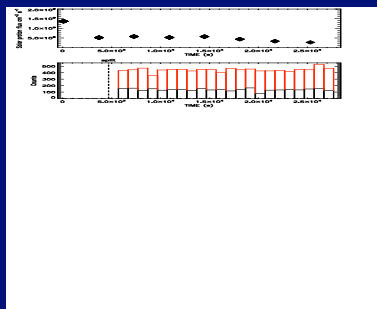
- Certain pointing angles not permitted

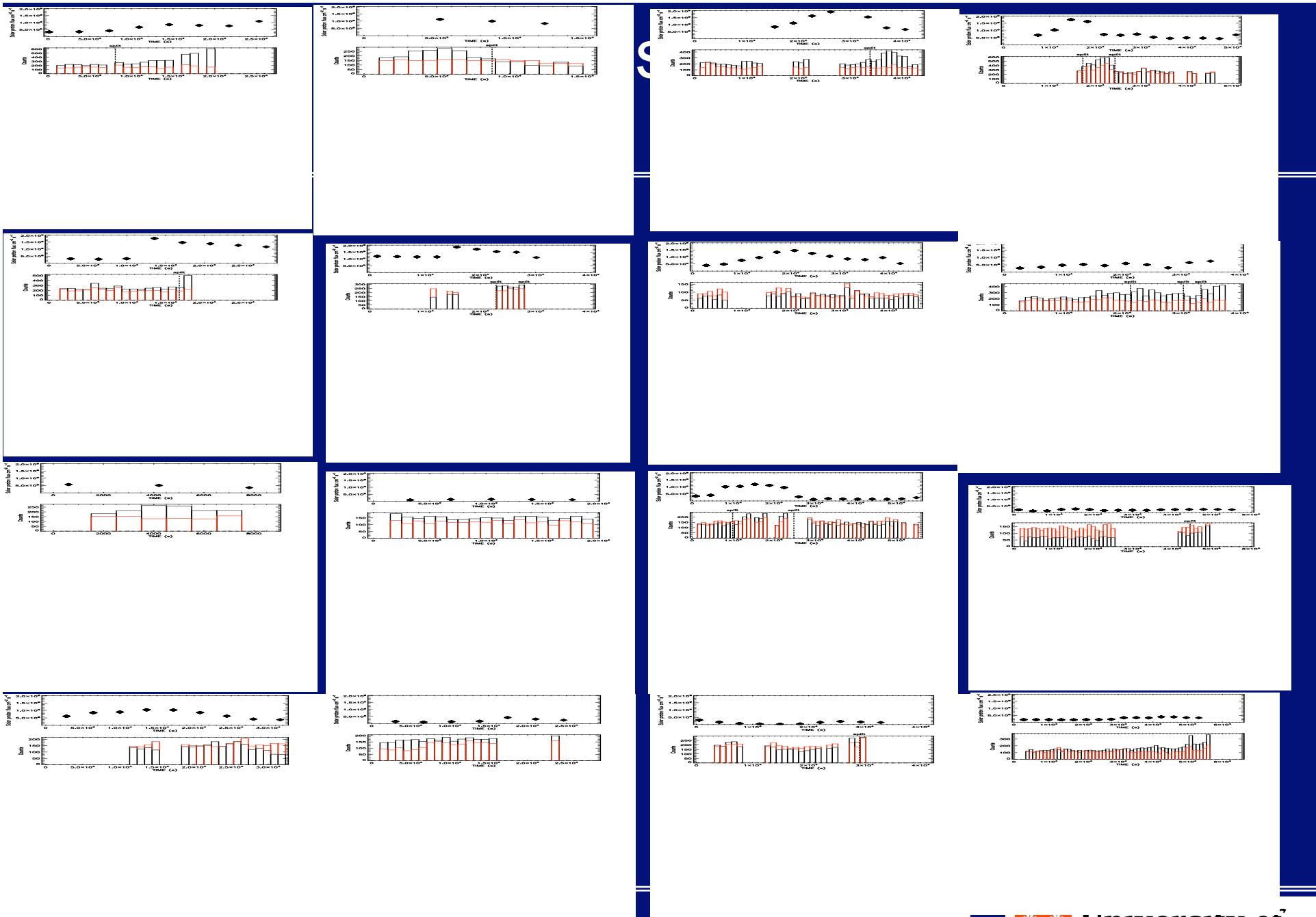
Parameter	Value
Solar Avoidance Angle	70 - 110°
Earth Limb Avoidance Angle	42°
Moon Avoidance Angle	22°
Moon Avoidance Angle (during eclipses)	35°
Size of the visibility bins	2°x 2°
Minimum Altitude for Observation (km)	46000

Extra lightcurves



Snowden et al. HDFN, 2004





April 2008
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Solar wind characteristics

- Fast solar wind
 - coronal holes at high latitude (700 – 800 km/s)
 - where mag. field lines are open
- Slow solar wind
 - low latitude (400 – 500 km/s)
 - enriched in Si, Mg, Fe c.f. fast wind
 - closed magnetic field lines, material in coronal loops
- Solar minimum: fast/slow wind situation as above
- Solar maximum: complicated situation, CMEs etc., lower charge states, similar hole temperatures although at lower latitude
- Mean free path of ions, v. hot, about 1AU, so no recombination

Khan and Cowley, magnetosheath distances

- Ann. Geophysocae 17, 1306-1335 (1999)
- They take from Roelof and Sibeck (1993), assuming $B_z = 0$
- $R_{mp} = 12.6/p(nPA)^{(1/6)}$
 $= 111/(n(\text{cm}^{-3}) * v(\text{km s}^{-1})) * R_e$
- $R_{bs} = 17.6/ p(nPA)^{(1/6)}$
 $= 162/ (n(\text{cm}^{-3}) * v(\text{km s}^{-1})) * R_e$